# HPV Robust Summaries and Test Plan

**CAS# 86508-42-1** Perfluoro compounds, C5-C18, including CAS#311-89-7 Perfluorotributyl amine

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# 1.0 Description of CAS number

## 1.1 Introduction

This HPV submission addresses a class of inert perfluorinated compounds (PFCs) covered by a single "generic" CAS# 86508-42-1, defined as "Perfluoro-compounds, C5-C18." (This "generic" CAS number is listed on the TSCA inventory based on the EPA's suggestion upon submittal of 3M's consolidated PMN 82-612 through 82-626.) Many compounds covered by this generic CAS number also have individual CAS numbers. However, only the generic CAS number and one individual CAS number (#311-89-7, perfluorotributyl amine) which is covered by the generic CAS number, are HPV chemicals based on the 1990 Inventory Use Reports used to designate HPV chemicals.

Data are available on a number of compounds within the generic CAS number for PFCs. This test plan presents existing data on ten different products that consist of various PFCs. It is well established that PFCs are chemically and biologically inert. Together the available data are ample to represent CAS # 86508-42-1, including CAS # 311-89-7, and no further testing is proposed.

PFCs are inert fluids composed of a complex combination of organic compounds resulting from the distillation of electrochemically fluorinated (ECF) compounds. This class consists of branched, linear and cyclic perfluorinated hydrocarbons having carbon numbers predominantly in the range of C5-C18 and boiling in the range of approximately 25° C to 255° C (77° F – 491° F). Perfluorinated amine and ether compounds may also be present.

3M manufactures a number of products comprised of PFCs, and markets them subject to rigorous product stewardship because of their photochemical stability and global warming potential. Section 1.2 lists ten products, each with its own individual CAS number, that are included under this "generic" CAS number and for which data are presented in this test plan. This listing is not intended to be inclusive of all possible chemicals covered by the generic CAS number. Rather, it represents the PFC products manufactured by 3M that were included in 3M's 1990 IUR submission. Data on these products adequately represent the generic CAS number.

CAS #311-89-7 is specifically identified in the title of this voluntary HPV submission because the EPA lists it as a separate HPV chemical. 3M did report this product separately in its 1990 IUR submission. However, CAS #311-89-7, like a number of other products with individual CAS numbers, is encompassed within the "generic" CAS number. It is included in this test plan, rather than separately, because it meets the toxicologic and environmental profile of this class of compounds. The term PFCs in this document encompasses CAS #311-89-7.

This test plan presents physical property data on each of ten PFC products. PFCs are highly volatile and insoluble in water. For the environmental and toxicological HPV endpoints, this test plan summarizes data from one or more PFC products. Data are available for almost all relevant endpoints, although certain physical property and environmental fate tests are not applicable. Ecotoxicity tests for fish and aquatic invertebrates show no toxicity; aquatic plant testing is deemed unnecessary. Acute toxicity, genotoxicity and repeat dose toxicity data are

available. Acute oral and inhalation toxicity tests show no toxicity at any dose tested, and even extremely high-dose intraperitoneal injection resulted in no lethality. Ames testing showed no genotoxicity. Inhalation exposure at levels up to 50,000 ppm for thirteen weeks produced no effects in rats, nor did oral exposure for thirty days at 2,000 mg/kg/day. Further testing for reproductive or developmental effects is unnecessary and inappropriate given that PFCs are chemically and biologically inert.

The compounds within this class of materials are all fully fluorinated and do not contain functional end-groups. As such, the materials within this class are all chemically and biologically inert. PFCs have high Henry's constants which dictate their environmental partitioning and, as described in Section 1.3, their low potential for interaction with biological membranes. The available data on this class of material demonstrates very consistent properties with regard to human health and environmental impact. The commonalities within this class are not surprising given the underlying physical/chemical properties.

While the presence of a nitrogen might, at first, offer the possibility that the PFC amines have a potentially reactive site for hydrolytic attack, the stereochemistry and electrochemistry of these compounds results in a partial delocalization of the pair of electrons on the nitrogen. Perfluorinated alkane moieties attached to the nitrogen are highly electron withdrawing. Additionally, this partial delocalization of the electron pair results in an "almost planar structure of the $NC_3$ unit." (10) These characteristics have the effect of significantly stabilizing these compounds, rendering them inert.

It has been noted that "Perfluoroaliphatic ethers and perfluorotertiary amines together with perfluoroalkanes and cycloalkanes comprise a class of extremely unreactive materials known in the industry as inert fluids." (11) The same reference also clarfies, "The inert character of the perfluoroethers and tertiary amines is demonstrated by their lack of basicity or reactivity as compared with their hydrocarbon analoques." This characteristic was also addressed as follows, "Perfluoro secondary amines, $(R_F)_2NH$ and perfluoropyridine ($C_5F_5N$) do not react with HCl or $BF_3$, and $(R_F)_3N$ amines have no basic character at all." (12)

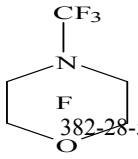
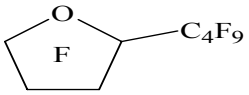
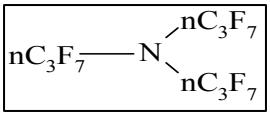
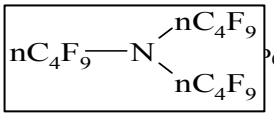
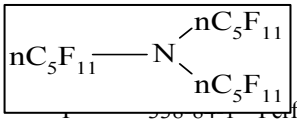
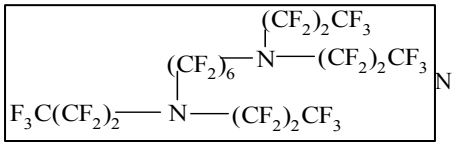
The chemical and biological stability of this class of materials also results in very long atmospheric lifetimes. The persistence of these materials in the atmosphere and their global warming potential are the primary consideration for the strict product stewardship associated with the marketing and use of these materials. That stewardship dictates that this class of materials be used in niche applications where there are no other alternatives available on the basis of performance or safety.

## 1.2 Identity of Substances and Structural Classification

3M manufactures ten products that fall within the generic CAS # 86508-42-1. As noted above, each of these products also has an individual CAS number, although EPA suggested use of the generic CAS number for inventory reporting.

The table below shows the composition of each PFC product, identifying the predominant molecule representing at least 50% of the total composition of the product as manufactured by

3M. The balance of each product is comprised of other PFCs with the same and similar number of carbon atoms in branched, linear and/or cyclic structure.

| Product | CAS# | Predominant Molecule | Structural Formula |
|---|---|---|---|
| A | 678-26-2 | Perfluoropentane (C5) | $CF_3CF_2CF_2CF_2CF_3$ |
| B | 382-28-5 | Perfluoro-N-methylmorpholine |  |
| C | 355-42-0 | Perfluorohexane (C6) | $CF_3CF_2CF_2CF_2CF_2CF_3$ |
| D | 335-57-9 | Perfluoroheptane (C7) | $CF_3CF_2CF_2CF_2CF_2CF_2CF_3$ |
| E | 307-34-6 | Perfluorooctane and | $CF_3CF_2CF_2CF_2CF_2CF_2CF_2CF_3$ |
| | 335-36-4 | Perfluoro-2-butyltetrahydrofuran (cyclic perfluoroether) |  |
| F | 307-34-6 | Perflurooctane (C8) | $CF_3CF_2CF_2CF_2CF_2CF_2CF_2CF_3$ |
| G | 338-83-0 | Perfluorotripropylamine |  |
| | | Perfluorotributylamine |  |
| | | Perfluorotriamylamine |  |
| | | N'-tetrapropyl |  |

## 1.3 Summary of Chemical and Physical Properties and Lack of Ecological and Toxicological Effects

PFCs are among the least toxic of all known organic chemicals. PFCs don't oxidize or hydrolyze. They have no functional reactive groups. PFCs owe their low toxicity to the combination of the following properties:

1. Chemical inertness
2. Low solubility in biological media (blood, cell membranes, etc.)
3. High volatility
4. Resistance to biological activation (reductive and oxidative metabolism)

Because PFCs are chemically inert, if inhaled and absorbed they do not react chemically with any biological molecules; they simply partition between blood and various organs and tissues. As PFCs have limited ability to dissolve in biological media, they do not reach appreciable concentrations in the tissues of air-exposed animals. As PFCs are highly volatile chemicals and have high air-blood partition coefficients, any fluorochemical remaining after exposure will be rapidly eliminated in the breath. Consequently, all such PFCs have:

1. Very high rodent LC50s (very low acute toxicity)
2. Very high cardiac sensitization EC50s (very low toxicity)

In fact, most PFCs do not induce narcosis (sleep) or cardiac sensitization at maximum achievable concentration (saturation).

PFCs are neutral molecules and because they are maximally fluorinated, they cannot undergo biological oxidation-reduction reactions to form reactive aldehydes, acid fluorides, radicals or acids that have been associated with several types of toxicity. As PFCs are not reactive directly with biological tissue and PFCs cannot form reactive metabolites, these fluorochemicals have tested negative in bacterial mutagenicity assays. Since PFCs are volatile and have limited water solubility, they also have very low toxicity when tested in fish and daphnia studies. These PFCs do not present any significant hazard to aquatic life.

Consequently, all PFCs that have undergone evaluation by the ACGIH or WEEL committees in the US have been granted an exposure guideline of 1000 ppm 8-hour Time Weighted Average (8-hr TWA). NASA has evaluated the toxicity information associated with PFCs including those that can be used as heat transfer agents and fire extinguishing agents in spacecraft and has established a Space Maximum Allowable Concentration (SMAC) of 11,000 ppm for up to 180 days (24 hours/day). (Chiu-Wing Lam, NASA, reference).

## 1.4 Use Pattern

PFCs are characterized as very stable, non-toxic liquids that have a very high dielectric and very low solubility for water and other airborne contaminants. These materials are also very insoluble in water. In other words, water does not go into PFCs and PFCs do not go into water. These specialty chemicals are used primarily in the industrial electronics industry for applications that exploit these specific properties. The principal applications include industrial heat transfer in semiconductor processing, electronics testing and solvents for computer disc drive lubrication.

Most applications where PFCs are used are regulated by section 612 of the Clean Air Act, which addresses the acceptability of alternatives for ozone-depleting substances. Based on the long atmospheric lifetime and high global warming potential of this class of materials, EPA regulations specify that PFCs may only be used as replacements for ozone-depleting substances in the regulated sectors where they are the only alternative available on the basis of either performance or safety. 3M follows this same guidance in applying product stewardship principles for supply of PFCs to unregulated sectors.

3M has manufactured PFCs at three sites in the U.S. Process improvements have reduced emissions 40% since 1995. 3M anticipates that installation of abatement technology in the next 3 years will reduce emissions to the environment by approximately 90% compared to the 1995 baseline. Although end-use applications are tightly controlled, emissions to the environment do occur at a very low rate. When emitted during manufacturing or from industrial use, the high Henry's Constant for this class of materials dictates preferential partitioning to the atmosphere.

# 2.0 HPV Test Plan

This chart represents the HPV Test Plan for CAS # 86508-42-1, Perfluoro compounds, C5-C18, including CAS # 311-89-7. This test plan reflects extensive existing data included in this submission. 3M does not propose additional testing.

| Endpoint | Information Available | Acceptable | Testing Needed |
|---|---|---|---|
| Physical Properties | | | |
| Melting Point | N/A | Yes | No |
| Boiling Point | Yes | Yes | No |
| Relative Density | Yes | Yes | No |
| Vapor Pressure | Yes | Yes | No |
| Octanol/Water Partition Coefficients | Yes | Yes | No |
| Water Solubility | Yes | Yes | No |
| pH and pKa Values | N/A | | No |
| Oxidation/Reduction Potential | N/A | | No |
| Adsorption/Desorption to Soil | N/A | | No |
| Environmental Fate and Pathways | | | |
| Photodegredation | Yes | Yes | No |
| Stability in Water | N/A | | No |
| Biodegredation | Yes | Yes | No |
| Fugacity | Yes | Yes | No |
| Ecotoxicity | | | |
| Acute Toxicity to Fish | Yes | Yes | No |
| Acute Toxicity to Aquatic Invertebrates | Yes | Yes | No |
| Acute Toxicity to Aquatic Plants | No | | No |
| Human Health Toxicity | | | |
| Acute Toxicity | Yes | Yes | No |
| Primary Irritation | Yes | Yes | No |
| Genotoxicity | | | |
| Point Mutation | Yes | Yes | No |
| Chromosomal Aberration | No | | No |
| Repeat dose Toxicity | Yes | Yes | No |
| Special Endpoints | Yes | Yes | No |
| Reproductive Toxicity | No | | No |
| Development and Teratogenicity Toxicity | No | | No |

# 3.0 Physical Properties

## 3.1 Melting Point

**MELTING POINT of class of compounds**

All materials in this class are in liquid state. For this class of compounds, pour point is generally used as a surrogate for melting point. Reference literature notes pour points of –74C and –50C for perfluorhexane and perfluorotributylamine, respectively. (11)

## 3.2 Boiling Point, 3.3 Relative Density, and 3.4 Vapor Pressure

Boiling point is measured based on ASTM D1120-65, "Boiling Point of Engine Antifreeze". The method for density measurement conforms to ASTM D4052-96, "Density and Relative Density of Liquids by Digital Density Meter"
Vapor Pressure measurements used ASTM E1719-97, "Vapor Pressure Measurement by Ebuilliometry".

| Product | CAS# | Predominant Molecule | Specification Median Boiling Point[1] (Centigrade) | Specification Median Density[1] (kg/m3) | Calculated Average Vapor Pressure[2] (pascals) |
|---|---|---|---|---|---|
| A | 678-26-2 | Perfluoropentane (C5) | 30 | 1648 | 81,100 |
| B | 382-28-5 | Perfluoro-N-methylmorpholine | 50 | 1709 | 35,700 |
| C | 355-42-0 | Perfluorohexane (C6) | 56* | 1675* | 30900* |
| D | 335-57-9 | Perfluoroheptane (C7) | 77-87 | 1726 | 10,600 |
| E | 307-34-6<br>335-36-4 | Perfluorooctane and cyclic perfluoroether | 97 | 1777 | 5,620 |
| F | 307-34-6 | Perfluorooctane (C8) | 101 | 1760 | 3,800 |
| G | 338-83-0 | Perfluorotripropylamine | 128 | 1817 | 1,440 |
| Ha | 311-89-7 | Perfluorotributylamine | 155* | 1850* | 432* |
| $H_b$ | 311-89-7 | Perfluorotributylamine | 174 | 1860 | 192 |
| I | 338-84-1 | Perfluorotriamylamine | 215 | 1940 | 15 |
| J | 143356-32-5 | Perfluoro-N,N,N',N'-tetrapropyl hexanediamine | 253 | 1900 | <2 |

**Report References:**

1 Manufacturing Plant QC test results on each Lot

2. Calculated average values were measured and extrapolated to STP (Standard Temperature & Pressure) using accepted values for constants A&B with the Clausius-Clapeyron equation.

* Verified, SMM Analytical Laboratory Report GID: 19159 dated July 16, 2001

## 3.5 Octanol/Water Partition Coefficients

Product **Ha**, CAS # 311-89-7, has been tested for octanol-water partitioning; the available data follow**.** Given the properties of PFCs, the likely ultimate fate of this class of compounds is release to the atmosphere, and modeling indicates partitioning to aquatic environments would be insignificant. Thus, octanol/water partitioning is insignificant to environmental risk assessment. 3M does not plan any additional testing on this property for these chemicals.

| | |
|---|---|
| **Test Substance:** | Test sample is product **Ha**. The production lot number was not noted. The purity of the substance cannot be verified to be 100%. The substance is a clear, colorless, odorless liquid. |
| **Method:** | 3M derived procedure using gas chromatography - 3M Commercial Chemicals Analytical group. |
| **GLP:** | No |
| **Year:** | 1981 |
| **Test procedure:** | The sample was prepared by mixing 25 uL of **Product Ha** with 100 mL of distilled water and shaking for 12 hours. A 50 mL aliquot was then shaken for 15 hours with 50 mL of prewater-saturated 99+% n-octanol. The mixture was allowed to stand for 2 hours. The n-octanol phase was analyzed directly, and the water phase was extracted with hexane and analyzed. Analysis was by gas chromatography. Distribution was determined by dividing the concentration in n-octanol by the concentration in water. |
| **Results:** | n-octanol concentration/water concentration = 557 |
| **Test Remarks:** | The test temperature was not recorded in the summary report. |
| **Conclusion:** | Though not conclusive, this study indicates that the octanol/water partition coefficient for **Product Ha** is 557. |
| **Data Quality:** | Klimisch ranking = 3. This study does not meet criteria for quality testing as temperature was not recorded |

| | |
|---|---|
| **Reference:** | 3M, Commercial Chemicals Analytical Request #17322 and Analytical Report #263 and #269. |

## 3.6 Water Solubility

Water solubility data are presented on Products **C** and **Ha**; the available data follows. While testing was conducted under informal R&D procedures, thus lacking full documentation, it is believed these results exemplify the low water solubility of this class of chemicals. The two chemicals tested fall into the lower molecular weight group and the upper molecular weight group. Product **C** represents the straight chain compounds while Product **Ha** represents the branched amines. Testing on these compounds indicates extremely low to no solubility.

| | |
|---|---|
| **Test Substance:** | **Product C**, production lot number 530. The substance is a clear, colorless, odorless liquid. Though primarily $C_6F_{14}$, the purity of the substance cannot be verified to be 100%. |
| **Method:** | 3M derived procedure using FT-NMR and GC - SA&CD/Group Analytical Lab Method #S-29-11-86 |
| **GLP:** | No |
| **Year:** | 1990 |
| **Test procedure:** | Sample 1 was created by agitating a 50%/50% distilled water/ **Product C** mixture for 16 hours. Analysis by FT-NMR was conducted 7 days later. Sample 2 was created by allowing a 50%/50% distilled water/ **Product C** mixture to sit in static contact for 16 hours. Analysis by FR-NMR was conducted 13 days after the initial contact with **Product C**. |
| **Results:** | Solubility at 25$^{o}$C (sample 1) = 33 mg/L<br>Solubility at 25$^{o}$C (sample 2) = <5 mg/L |
| **Test Remarks:** | The substance detected in the agitated water phase may be in an emulsified form and not in a true solution form. |
| **Conclusion:** | Solubility of the test substance is likely to be less than 33 mg/L and may be less than 5 mg/L. Low water solubility is indicative of the class of compounds covered by CAS number 86508-42-1. |

| | |
|---|---|
| **Data Quality:** | Klimisch ranking = 3. This study does not meet criteria for quality testing. The procedure failed to differentiate between solubilized material and emulsified material. |
| **Reference:** | 3M Specialty Adhesives and Chemicals / Group Analytical Laboratory, Request number 35219. Project number 9204300014. |

* * *

| | |
|---|---|
| **Test Substance:** | Test sample is **Product Ha**. The production lot number was not noted. The purity of the substance cannot be verified to be 100%. The substance is a clear, colorless, odorless liquid. |
| **Method:** | 3M derived procedure using gas chromatography - 3M Commercial Chemicals Analytical group. |
| **GLP:** | No |
| **Year:** | 1981 |
| **Test procedure:** | One sample consisted of 25 uL of **Product Ha** added to 100 mL of distilled water and shaken for 12 hours. Another sample was prepared by adding 5 uL of **Product Ha** to 1000 mL of distilled water and shaken for 12 hours. These samples were allowed to stand for 15 hours and then centrifuged. 25 mL aliquots of each were extracted with three consecutive 5 mL aliquots of hexane and the extracts were analyzed separately by gas chromatography. |
| **Results:** | Water solubility was indicated to be 0.68 ppm. |
| **Test Remarks:** | Detection limit for the method was 0.03 ppm. The test temperature was not recorded in the summary report. It is not disclosed if the samples were allowed to sit open to the environment or if they were closed during the 15-hour rest period. |
| **Conclusion:** | Though not conclusive, this study indicates that the solubility of the test substance is <1 ppm. Low water solubility is indicative of the class of compounds covered by CAS number 86508-42-1. |

| | |
|---|---|
| **Data Quality:** | Klimisch ranking = 3. This study does not meet criteria for quality testing. Proper documentation of test conditions was not followed. |
| **Reference:** | 3M, Commercial Chemicals Analytical Request #17322 and Analytical Report #263 and #269. |

## 3.7 pH and pKa Values

**pH and pKa VALUES –** NOT RELEVANT

There is no water in any of these material so no ionization occurs.

## 3.8 Oxidation-Reduction Potential

**Oxidation-Reduction Potential –** NOT APPLICABLE

3M has experience to demonstrate that the standard oxidation-reduction potentials do not apply to PFCs. The materials are unaffected by electrochemical reactions and do not dissociate in aqueous media. They are essentially already fully oxidized and are unaffected by standard oxidizing agents such as permanganates, chromates, etc. The only known oxidation takes place only at high temperatures by thermal decomposition. Likewise, the materials are only reduced under extreme conditions, requiring reducing agents such as elemental sodium.

## 3.9 Adsorption/Desorption to Soil

**Adsorption/Desorption to Soil** - NOT APPLICABLE

As outlined in the explanation for how these chemicals are used, the predominant release of these chemicals will be to the atmosphere. Because of the volatility of these compounds, OECD methods do not apply. Any testing of these compounds would have to be done utilizing experimental procedures at significant cost. Since this property is not important to environmental risk assessment of these compounds, 3M will not undertake testing for adsorption/desorption to soil.

# 4.0 Environmental Fate and Pathways

## 4.1 Photodegradation

Extensive research has addressed the photodegradation of this class of compounds. The following is information that was presented to the United States Environmental Protection Agency resulting in the successful elimination of this chemical class from regulation as VOCs based on their photochemical stability.

**Test Substance:** C5-C18 perfluorinated chemicals covered by CAS number 86508-42-1.

**Method:** Calculated

**GLP:** No

**Year:** 1990

**Overview:**

R. J. Cicerone[1] published theoretical calculations indicating that the perfluorochemical, carbon tetrafluoride, is essentially inert in the atmosphere. His calculations predicted an atmospheric lifetime of more than 10,000 years. In addressing reactions with hydroxyl radicals, Cicerone states: "Reactions of ground-state OH· with $CF_4$ are strongly endothermic and thus negligible." To support this statement, Cicerone presented the following candidate reactions between hydroxyl radical and $CF_4$ (Rx. 1. – Rx. 3.) with calculated enthalpies:

| Reaction | ΔH298 (kcal/mole) | |
|---|---|---|
| $OH\cdot + CF_4 \rightarrow FO + CF_3H$ | +73.0 | Rx. 1. |
| $OH\cdot + CF_4 \rightarrow HOF + CF_3$ | +70.2 | Rx. 2. |
| $OH\cdot + CF_4 \rightarrow$ other products | +77 | Rx. 3. |

Extrapolation from $CF_4$ to other perfluoroalkanes is reasonably straightforward. Fabian, et al. quote the >10,000 year lifetime calculated by Cicerone and state"… a similar lifetime can be assumed for C2F6…".[2]

Reactions 4., 5., and 6., given below, show that, at least in terms of hydroxyl radical reactions with perfluorocarbons, this is a reasonable extrapolation. Reaction 4. and 5. show that the fluorine radical (F·) is more reactive with hydrogen containing organic materials than the hydroxyl radical, while reaction

4. shows that reaction between the more reactive F· and a perfluorocarbon (RF) is very unfavored energetically.

| Reaction | ΔH (kcal/mole) | |
|---|---|---|
| $RH + F\cdot \rightarrow R\cdot + HF$ | -34 | Rx. 4.[3] |
| $RH\cdot + OH\cdot \rightarrow R\cdot + H_2O$ | -13 | Rx. 5.[4] |
| $RF\cdot + F\cdot \rightarrow R\cdot + F_2$ | +68 | Rx. 6.[3] |

Expressed more graphically, mixing F· with ethane would yield an explosive reaction, but mixing F· radical with a perfluorocarbon, would lead to no reaction at all. One can conclude from the above that the reaction rate between a perfluoroalkane and OH· is much less than that between a OH· and ethane.

The most potentially reactive of this perfluorocarbon class, the perfluorinated tertiary amines and the quite analogous perfluorinated ethers, are similarly unreactive. This is supported by the following statement from Fluorine in Organic Chemistry: [5] "Perfluoro tertiary amines $(R_f)_3N$ are very inert systems and are more akin to perfluoroalkanes than amines." Ulmann's Encyclopedia of Industrial Chemistry also addresses the inertness of perfluoroalkyl tertiary amines.[6] This article states:

> "The electron-withdrawing nature of the perfluoroalkyl substituents deprives the nitrogen atom of its basic character and reactivity. Fluorinated *tert*-amines do not form salts or complexes with strong acids and are not attacked by most oxidizing or reducing agents."

Studies conducted by 3M show that perfluoro tertiary amines don't react with fluorine radicals under room temperature conditions[7]. These studies offer further confirmation that perfluoro tertiary amines like perfluoroalkanes are extremely stable. The similar inertness of perfluoroethers is implicitly shown in a European patent application on a process for preparing perfluoroethers with elemental fluorine.[8] In this process, a perfluoroether used as a solvent for this reaction is later recovered, demonstrating the stability of the perfluoroether to fluorine radical.

Numerous published articles show that no degradation of perfluorocarbons is expected in the troposphere.[9-17] McElroy et al. investigated the atmospheric fate of various perfluorinated compounds including C6 to $C_{10}$ perfluoroalkanes. They concluded that perfluorocarbons do not react at significant rates with hydroxyl radicals and that such compounds will only degrade in the upper atmosphere through reactions with O(1D) yielding an approximate average atmospheric lifetime of 1,000 years. More recent work at MIT has shown that perfluoroalkanes do not react with 0(1D), at least not at rates comparable to those of CFCs. These newer findings suggests that reactions with 0(1D) in the

stratosphere would not play a significant role in the degradation of perfluoroalkanes.

Ko et al. predict the photo- and oxidative-degradation rates of the perfluorochemical based on UV absorption spectra and assumed quantum yields.[10] They conclude that photodegradation would not occur in the troposphere. Calloway et al. further evaluate the UV absorption spectra of perfluoroalkanes and perfluoro-aromatic molecules.[11] This work shows that absorption spectra of perfluorocarbons occur at wave lengths too short to allow direct photodissociation in the troposphere. UV absorption maxima of perfluoroalkanes are generally below 190 nm. Most aromatic perfluorochemicals have absorption onsets below 260 to 280 nm, but some, such as perfluoronaphthalene, have absorption as high as 330 nm.

Yet another demonstration of the photochemical stability of perfluorochemicals is their use as inert solvents in a study reported by Chen et al. of the UV photolysis of other organic compounds.[12] Similarly, 3M has used liquid perfluoroalkanes and perfluoroethers as coolants for photochemical reactors, a use in which they receive intense exposure to UV light without photodegrading.

A very clear demonstration of the stability of saturated perfluorocarbons can be ascertained from the measurements by Dietz et al.[13] They measured the atmospheric concentrations of two fluorocarbons, perfluoromonomethylcyclohexane and perfluorodimethylcyclohexane. The bulk of these two fluorocarbons had been released to the atmosphere 30 to 40 years prior to Dietz's measurements, yet they were present in the atmosphere at near the cumulative concentration expected from their total worldwide production.

References: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16. Sandorfy, C., UV Absorption of Fluorocarbons, Atmospheric Environment, Vol. 10, p343, 1976.
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**Conclusion:**

The class of compounds covered by CAS number 86508-42-1 are photochemically stable.

**Data Quality:** This information is considered reliable.

**Reference:**

Submission to THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY by THE MINNESOTA MINING AND MANUFACTURING COMPANY, *Request for the Exemption of Certain Perfluorocarbon Compounds From Regulation Under the Clean Air Act as Precursors to Tropospheric Ozone*, February 16, 1990.

## 4.2 Stability in Water

These compounds are highly volatile and insoluble. They are therefore not likely to partition to aquatic environments from the atmosphere. These compounds are extremely unlikely to undergo hydrolysis and testing is unnecessary.

The stability of both PFC alkanes and PFC amines in water can be addressed by their structural properties.

PFC alkanes lack any functional groups / reactive sites that would make them open to hydrolytic attack.

While the presence of a nitrogen might at first offer the possibility that the PFC amines have a potentially reactive site for hydrolytic attack, the stereochemistry and electrochemistry of these compounds results in a partial delocalization of the pair of electrons on the nitrogen. Perfluorinated alkane moieties attached to the nitrogen are highly electron withdrawing. Additionally, this partial delocalization of the electron pair results in an "almost planar structure of the $NC_3$ unit." (10) These characteristics have the effect of significantly stabilizing these compounds, again, rendering them inert to hydrolytic reactions. This fact is further substantiated in that perfluorotributylamine has been studied as a blood substitute in part because of its stability.

## 4.3 Biodegradation

PFCs are not biodegradable. As an example, 3M presents data on Product **Ha.**

| | |
|---|---|
| **Test Substance:** | **Product Ha,** production lot number not noted. The purity of the substance cannot be verified to be 100%. The substance is a clear, colorless, odorless liquid. |
| **Method:** | 3M BOD/COD tests – method not recorded |
| **Test solutions:** | 3.0 g **Product Ha**/ 300 ml = 10,000 mg **Product Ha**/L |
| **Medium:** | BOD water inoculated at 6 mg/L with stale sewage from 3M's wastewater treatment plant in Cottage Grove, MN |
| **GLP:** | No |
| **Year:** | 1981 |
| **Results:** | BOD 5 days < 200 mg/kg<br>BOD 10 days < 200 mg/kg<br>BOD 20 days < 200 mg/kg |

| | |
|---|---|
| **Remarks:** | Water is not a likely environmental release media. The substance was tested in duplicate. The primary standard solution (glucose-glutamic acid) met requirements for biodegradation. No toxicity control was conducted. Testing was conducted well above the solubility limit of this material. |
| **Conclusion:** | The substance was not found to be biodegradable. This result is representative of the class of compounds covered by CAS number 86508-42-1. |
| **Data Quality:** | Klimisch ranking = 3. This study does not meet criteria for quality testing. Though not expected to be toxic to wastewater organisms (analogy to the ecotoxicity data provided), this test fails to differentiate between lack of biodegradation activity and potential toxicity effects on the organisms. However, as the likely ultimate fate of this class of compounds is release to the atmosphere, and modeling indicates partitioning to aquatic environments would be insignificant, this property is not vital to environmental risk assessment. 3M respectfully requests waiver of any further testing on this property for these chemicals. |
| **Reference:** | 3M, Environmental Laboratory – laboratory request number –7044 |

## 4.4 Fugacity

As outlined in the explanation for how these chemicals are used, the predominant release of these chemicals will be to the atmosphere. Calculated Henry's Law Constants for these compounds indicate that a release of the liquid material would result in a relatively rapid volatilization to the air. For this reason, fugacity modeling has been approached assuming 100% release to the atmosphere. Modeling for 3 compounds has been included to cover the range of chemicals, and was conducted utilizing the Level III Fugacity Model as part of the Syracuse Research Corporation EPISuite package available from the U.S. EPA. This modeling indicates that, once released to the atmosphere, it is expected to stay in the atmosphere.

**Product A**

```
Level III Fugacity Model (Full-Output):
=======================================
  Chem Name   : Pentane, dodecafluoro-
  Molecular Wt: 288.04
```

```
  Henry's LC  : 3.5e+003 atm-m3/mole (Henrywin program)
  Vapor Press : 608 mm Hg  (user-entered)

           Mass Amount    Half-Life    Emissions
            (percent)        (hr)       (kg/hr)
   Air       100             1e+005       1000
   Water     1.07e-006       3.6e+003     0
   Soil      0.00363         3.6e+003     0
   Sediment  8.84e-007       1.44e+004    0

             Fugacity    Reaction    Advection   Reaction    Advection
              (atm)      (kg/hr)      (kg/hr)    (percent)   (percent)
   Air       8.48e-011    0.693       999         0.0693      99.9
   Water     6.4e-011     2.06e-007   1.07e-006   2.06e-008   1.07e-007
   Soil      8.47e-011    0.000698    0           6.98e-005   0
   Sediment  1.08e-010    4.25e-008   1.77e-008   4.25e-009   1.77e-009

   Persistence Time: 99.9 hr
   Reaction Time:    1.44e+005 hr
   Advection Time:   100 hr
   Percent Reacted:  0.0693
   Percent Advected: 99.9

   Half-Lives (hr), (based upon Biowin (Ultimate) and Aopwin):
      Air:      1e+005
      Water:    3600
      Soil:     3600
      Sediment: 1.44e+004
        Biowin estimate: 0.900  (recalcitrant)

   Advection Times (hr):
      Air:      100
      Water:    1000
      Sediment: 5e+004
```

**Product F**

```
Level III Fugacity Model (Full-Output):
=======================================
  Chem Name   : Octane, octadecafluoro-
  Molecular Wt: 438.06
  Henry's LC  : 5.08e+005 atm-m3/mole (Henrywin program)
  Vapor Press : 28.5 mm Hg  (user-entered)

           Mass Amount    Half-Life    Emissions
            (percent)        (hr)       (kg/hr)
   Air       100             1e+005       1000
   Water     2.02e-006       3.6e+003     0
   Soil      0.00436         3.6e+003     0
   Sediment  0.000104        1.44e+004    0

             Fugacity    Reaction    Advection   Reaction    Advection
              (atm)      (kg/hr)      (kg/hr)    (percent)   (percent)
   Air       5.57e-011    0.693       999         0.0693      99.9
   Water     1.94e-010    3.88e-007   2.01e-006   3.88e-008   2.01e-007
   Soil      5.57e-011    0.000838    0           8.38e-005   0
```

```
   Sediment  3.44e-010    5e-006      2.08e-006   5e-007      2.08e-007

   Persistence Time: 99.9 hr
   Reaction Time:    1.44e+005 hr
   Advection Time:   100 hr
   Percent Reacted:  0.0693
   Percent Advected: 99.9

   Half-Lives (hr), (based upon Biowin (Ultimate) and Aopwin):
      Air:      1e+005
      Water:    3600
      Soil:     3600
      Sediment: 1.44e+004
        Biowin estimate: -0.068  (recalcitrant)

   Advection Times (hr):
      Air:      100
      Water:    1000
      Sediment: 5e+004
```

**Product I**

```
Level III Fugacity Model (Full-Output):
=======================================
  Chem Name   : Pentanamine, 1,1,2,2,3,3,4,4,5,5,5-undecafluoro-N,N-
bis(undecafl
oropentyl)-
  Molecular Wt: 821.12
  Henry's LC  : 7.91e+006 atm-m3/mole (Henrywin program)
  Vapor Press : 0.014 mm Hg  (user-entered)

            Mass Amount    Half-Life    Emissions
             (percent)        (hr)       (kg/hr)
   Air       96.7            1e+005       1000
   Water     0.00398         3.6e+003     0
   Soil      3.05            3.6e+003     0
   Sediment  0.209           1.44e+004    0

             Fugacity    Reaction    Advection   Reaction    Advection
              (atm)      (kg/hr)      (kg/hr)    (percent)   (percent)
   Air       2.97e-011    0.692       999         0.0692      99.9
   Water     3.92e-011    0.00079     0.00411     7.9e-005    0.000411
   Soil      2.25e-011    0.606       0           0.0606      0
   Sediment  6.95e-011    0.0104      0.00431     0.00104     0.000431

   Persistence Time: 103 hr
   Reaction Time:    7.89e+004 hr
   Advection Time:   103 hr
   Percent Reacted:  0.131
   Percent Advected: 99.9

   Half-Lives (hr), (based upon Biowin (Ultimate) and Aopwin):
      Air:      1e+005
      Water:    3600
```

```
      Soil:     3600
      Sediment: 1.44e+004
        Biowin estimate: -2.955  (recalcitrant)

   Advection Times (hr):
      Air:      100
      Water:    1000
      Sediment: 5e+004
```

Attachment: **Level III Fugacity Model Output for Perfluorotributylamine**

```
Level III Fugacity Model (Full-Output):
=======================================
  Chem Name   : 1-Butanamine, 1,1,2,2,3,3,4,4,4-nonafluoro-N,N-
bis(nonafluorobut
l)-
  Molecular Wt: 671.1
  Henry's LC  : 4.21 atm-m3/mole (calc VP/Wsol)
  Vapor Press : 3.24 mm Hg  (user-entered)
  Log Kow     : 2.75  (user-entered)
  Soil Koc    : 231  (calc by model)

            Mass Amount    Half-Life    Emissions
             (percent)        (hr)       (kg/hr)
   Air       48.9            1e+005       1000
   Water     49.9            4.32e+003    1000
   Soil      0.431           8.64e+003    1000
   Sediment  0.767           3.89e+004    0

             Fugacity    Reaction    Advection   Reaction    Advection
              (atm)      (kg/hr)      (kg/hr)    (percent)   (percent)
   Air       9.76e-011    1.86        2.68e+003   0.0619      89.4
   Water     8.56e-006    43.8        273         1.46        9.11
   Soil      2.04e-008    0.189       0           0.00631     0
   Sediment  1.01e-005    0.0749      0.084       0.0025      0.0028

   Persistence Time: 183 hr
   Reaction Time:    1.19e+004 hr
   Advection Time:   185 hr
   Percent Reacted:  1.53
   Percent Advected: 98.5

   Half-Lives (hr), (based upon Biowin (Ultimate) and Aopwin):
      Air:      1e+005
      Water:    4320
      Soil:     8640
      Sediment: 3.888e+004
        Biowin estimate: -1.987  (recalcitrant)

   Advection Times (hr):
      Air:      100
      Water:    1000
      Sediment: 5e+004
```

```
Level III Fugacity Model (Full-Output):
=======================================
  Chem Name   : 1-Butanamine, 1,1,2,2,3,3,4,4,4-nonafluoro-N,N-
bis(nonafluorobut
l)-
  Molecular Wt: 671.1
  Henry's LC  : 4.21 atm-m3/mole (calc VP/Wsol)
  Vapor Press : 3.24 mm Hg  (user-entered)
  Log Kow     : 2.75  (user-entered)
  Soil Koc    : 231  (calc by model)

           Mass Amount    Half-Life    Emissions
            (percent)        (hr)       (kg/hr)
   Air       100             1e+005       1000
   Water     0.000825        4.32e+003    0
   Soil      0.00421         8.64e+003    0
   Sediment  1.27e-005       3.89e+004    0

             Fugacity    Reaction    Advection   Reaction    Advection
              (atm)      (kg/hr)      (kg/hr)    (percent)   (percent)
   Air       3.64e-011    0.693       999         0.0693      99.9
   Water     2.58e-011    0.000132    0.000824    1.32e-005   8.24e-005
   Soil      3.64e-011    0.000338    0           3.38e-005   0
   Sediment  3.04e-011    2.26e-007   2.54e-007   2.26e-008   2.54e-008

   Persistence Time: 99.9 hr
   Reaction Time:    1.44e+005 hr
   Advection Time:   100 hr
   Percent Reacted:  0.0693
   Percent Advected: 99.9

   Half-Lives (hr), (based upon Biowin (Ultimate) and Aopwin):
      Air:      1e+005
      Water:    4320
      Soil:     8640
      Sediment: 3.888e+004
        Biowin estimate: -1.987  (recalcitrant)

   Advection Times (hr):
      Air:      100
      Water:    1000
      Sediment: 5e+004


Level III Fugacity Model (Full-Output):
=======================================
  Chem Name   : 1-Butanamine, 1,1,2,2,3,3,4,4,4-nonafluoro-N,N-
bis(nonafluorobut
l)-
  Molecular Wt: 671.1
  Henry's LC  : 4.21 atm-m3/mole (calc VP/Wsol)
  Vapor Press : 3.24 mm Hg  (user-entered)
  Log Kow     : 2.75  (user-entered)
  Soil Koc    : 231  (calc by model)

           Mass Amount    Half-Life    Emissions
            (percent)        (hr)       (kg/hr)
```

```
   Air       19.7            1e+005       0
   Water     79              4.32e+003    1000
   Soil      0.000831        8.64e+003    0
   Sediment  1.22            3.89e+004    0

             Fugacity    Reaction    Advection   Reaction    Advection
              (atm)      (kg/hr)      (kg/hr)    (percent)   (percent)
   Air       2.48e-011    0.473       682         0.0473      68.2
   Water     8.56e-006    43.8        273         4.38        27.3
   Soil      2.48e-011    0.00023     0           2.3e-005    0
   Sediment  1.01e-005    0.0749      0.084       0.00749     0.0084

   Persistence Time: 346 hr
   Reaction Time:    7.79e+003 hr
   Advection Time:   362 hr
   Percent Reacted:  4.44
   Percent Advected: 95.6

   Half-Lives (hr), (based upon Biowin (Ultimate) and Aopwin):
      Air:      1e+005
      Water:    4320
      Soil:     8640
      Sediment: 3.888e+004
        Biowin estimate: -1.987  (recalcitrant)

   Advection Times (hr):
      Air:      100
      Water:    1000
      Sediment: 5e+004


Level III Fugacity Model (Full-Output):
=======================================
  Chem Name   : 1-Butanamine, 1,1,2,2,3,3,4,4,4-nonafluoro-N,N-
bis(nonafluorobut
l)-
  Molecular Wt: 671.1
  Henry's LC  : 4.21 atm-m3/mole (calc VP/Wsol)
  Vapor Press : 3.24 mm Hg  (user-entered)
  Log Kow     : 2.75  (user-entered)
  Soil Koc    : 231  (calc by model)

            Mass Amount    Half-Life    Emissions
             (percent)        (hr)       (kg/hr)
   Air       97.7            1e+005       0
   Water     0.00471         4.32e+003    0
   Soil      2.3             8.64e+003    1000
   Sediment  7.24e-005       3.89e+004    0

             Fugacity    Reaction    Advection   Reaction    Advection
              (atm)      (kg/hr)      (kg/hr)    (percent)   (percent)
   Air       3.64e-011    0.692       999         0.0692      99.9
   Water     1.51e-010    0.000772    0.00481     7.72e-005   0.000481
   Soil      2.03e-008    0.189       0           0.0189      0
   Sediment  1.78e-010    1.32e-006   1.48e-006   1.32e-007   1.48e-007

   Persistence Time: 102 hr
```

```
   Reaction Time:    1.16e+005 hr
   Advection Time:   102 hr
   Percent Reacted:  0.0882
   Percent Advected: 99.9

   Half-Lives (hr), (based upon Biowin (Ultimate) and Aopwin):
      Air:      1e+005
      Water:    4320
      Soil:     8640
      Sediment: 3.888e+004
        Biowin estimate: -1.987  (recalcitrant)

   Advection Times (hr):
      Air:      100
      Water:    1000
      Sediment: 5e+004


Level III Fugacity Model (Full-Output):
=======================================
  Chem Name   : 1-Butanamine, 1,1,2,2,3,3,4,4,4-nonafluoro-N,N-
bis(nonafluorobut
l)-
  Molecular Wt: 671.1
  Henry's LC  : 4.21 atm-m3/mole (calc VP/Wsol)
  Vapor Press : 3.24 mm Hg  (user-entered)
  Log Kow     : 2.75  (user-entered)
  Soil Koc    : 231  (calc by model)

            Mass Amount    Half-Life    Emissions
             (percent)        (hr)       (kg/hr)
   Air       37.7            1e+005       1000
   Water     61.3            4.32e+003    1000
   Soil      0.00159         8.64e+003    0
   Sediment  0.943           3.89e+004    0

              Fugacity    Reaction    Advection   Reaction    Advection
               (atm)      (kg/hr)      (kg/hr)    (percent)   (percent)
   Air       6.12e-011    1.17        1.68e+003   0.0583      84.1
   Water     8.56e-006    43.8        273         2.19        13.7
   Soil      6.12e-011    0.000568    0           2.84e-005   0
   Sediment  1.01e-005    0.0749      0.084       0.00374     0.0042

   Persistence Time: 223 hr
   Reaction Time:    9.89e+003 hr
   Advection Time:   228 hr
   Percent Reacted:  2.25
   Percent Advected: 97.7

   Half-Lives (hr), (based upon Biowin (Ultimate) and Aopwin):
      Air:      1e+005
      Water:    4320
      Soil:     8640
      Sediment: 3.888e+004
        Biowin estimate: -1.987  (recalcitrant)

   Advection Times (hr):
```

```
      Air:      100
      Water:    1000
      Sediment: 5e+004


Level III Fugacity Model (Full-Output):
=======================================
  Chem Name   : 1-Butanamine, 1,1,2,2,3,3,4,4,4-nonafluoro-N,N-
bis(nonafluorobut
l)-
  Molecular Wt: 671.1
  Henry's LC  : 4.21 atm-m3/mole (calc VP/Wsol)
  Vapor Press : 3.24 mm Hg  (user-entered)
  Log Kow     : 2.75  (user-entered)
  Soil Koc    : 231  (calc by model)

            Mass Amount    Half-Life    Emissions
             (percent)        (hr)       (kg/hr)
   Air       98.8            1e+005       1000
   Water     0.00279         4.32e+003    0
   Soil      1.17            8.64e+003    1000
   Sediment  4.29e-005       3.89e+004    0

             Fugacity    Reaction    Advection   Reaction    Advection
              (atm)      (kg/hr)      (kg/hr)    (percent)   (percent)
   Air       7.28e-011    1.38        2e+003      0.0692      99.9
   Water     1.77e-010    0.000905    0.00564     4.52e-005   0.000282
   Soil      2.04e-008    0.189       0           0.00945     0
   Sediment  2.08e-010    1.55e-006   1.73e-006   7.73e-008   8.67e-008

   Persistence Time: 101 hr
   Reaction Time:    1.28e+005 hr
   Advection Time:   101 hr
   Percent Reacted:  0.0787
   Percent Advected: 99.9

   Half-Lives (hr), (based upon Biowin (Ultimate) and Aopwin):
      Air:      1e+005
      Water:    4320
      Soil:     8640
      Sediment: 3.888e+004
        Biowin estimate: -1.987  (recalcitrant)

   Advection Times (hr):
      Air:      100
      Water:    1000
      Sediment: 5e+004


Level III Fugacity Model (Full-Output):
=======================================
  Chem Name   : 1-Butanamine, 1,1,2,2,3,3,4,4,4-nonafluoro-N,N-
bis(nonafluorobut
l)-
  Molecular Wt: 671.1
  Henry's LC  : 4.21 atm-m3/mole (calc VP/Wsol)
  Vapor Press : 3.24 mm Hg  (user-entered)
```

```
Log Kow     : 2.75  (user-entered)
Soil Koc    : 231  (calc by model)

          Mass Amount    Half-Life    Emissions
           (percent)        (hr)       (kg/hr)
 Air       37.5            1e+005       0
 Water     61              4.32e+003    1000
 Soil      0.526           8.64e+003    1000
 Sediment  0.938           3.89e+004    0

           Fugacity    Reaction    Advection   Reaction    Advection
            (atm)      (kg/hr)      (kg/hr)    (percent)   (percent)
 Air       6.12e-011    1.17        1.68e+003   0.0583      84.1
 Water     8.56e-006    43.8        273         2.19        13.7
 Soil      2.04e-008    0.189       0           0.00944     0
 Sediment  1.01e-005    0.0749      0.084       0.00374     0.0042

 Persistence Time: 224 hr
 Reaction Time:    9.9e+003 hr
 Advection Time:   229 hr
 Percent Reacted:  2.26
 Percent Advected: 97.7

 Half-Lives (hr), (based upon Biowin (Ultimate) and Aopwin):
    Air:      1e+005
    Water:    4320
    Soil:     8640
    Sediment: 3.888e+004
      Biowin estimate: -1.987  (recalcitrant)

 Advection Times (hr):
    Air:      100
    Water:    1000
    Sediment: 5e+004
```

# 5.0 Ecotoxicity

## 5.1 Acute Toxicity to Fish

This class of chemicals presents no aquatic toxicity due to the lack of water solubility, as demonstrated in test data on several products.

| | |
|---|---|
| **Test Substance:** | **Product C**, production lot number 530. The substance is a clear, colorless, odorless liquid. The purity of the substance cannot be verified to be 100%. |
| **Method:** | Modeled after ASTM E729-80. Standard for conducting acute toxicity tests with fishes, macro-invertebrates, and amphibians. American Society for Testing and Materials, Philadelphia, PA 1980. |

| | |
|---|---|
| **Test Type:** | Acute Static |
| **Test solutions:** | Well water used as vehicle. 2 control vessels and 2 vessels at 1000 mg/l of Product C (direct addition of individually measured weights). |
| **Test organism:** | Fathead minnow (*Pimephales promelas*) with average length of 2.4 cm and average weight of 0.1 grams. |
| **Exposure Period:** | 96 hours |
| **Analytical Monitoring:** | pH, dissolved oxygen, and temperature. All remained within acceptable parameters throughout the test. |
| **GLP:** | No |
| **Year:** | 1982 |
| **Results:** | $LC_{50}$ = > 1000 mg/l (Today, this would be termed an $LL_{50}$ = Median Lethal Loading.) |
| **Test Remarks:** | Water is not a likely environmental release media. The substance is not soluble in water and remains as a separate phase on the tank bottom. Exposure was therefore to a saturated solution. The loading factor for the test was 0.10 g/L utilizing 30 organisms per dose. |
| **Conclusion:** | No adverse affects or mortality occurred during this study. The 96-hr. LC50 for fathead minnows therefore exceeds the solubility limit for the test substance. This result is representative of the class of compounds covered by CAS number 86508-42-1. |
| **Data Quality:** | Klimisch ranking = 2. This study meets most of the criteria for quality testing. Proper documentation of the test method and parameters was followed. However, no analysis of the actual test substance concentration was made, nor was there proper analytical characterization of the sample itself. |
| **Reference:** | 3M, Environmental Laboratory – laboratory request number 7842 |

* * *

| | |
|---|---|
| **Test Substance:** | **Product Ha**, production lot number 501. The purity of the substance cannot be verified to be 100%. The substance is a clear, colorless, odorless liquid. |
| **Method:** | Modeled after ASTM E729-80. Standard for conducting acute toxicity tests with fishes, macro-invertebrates, and amphibians. American Society for Testing and Materials, Philadelphia, PA 1980. |
| **Test Type:** | Acute Static |
| **Test Solutions:** | Well water used as vehicle. 2 control vessels and test vessels containing Product Ha concentrations of 10, 100, 1000, 2000, and 4000 mg/l (direct addition of individually measured weights). |
| **Test organism:** | Fathead minnow (*Pimephales promelas*) with average length of 3.0 cm and average weight of 0.251 grams. |
| **Exposure Period:** | 96 hours |
| **Analytical Monitoring:** | pH, dissolved oxygen, and temperature. All remained within acceptable parameters throughout the test. |
| **GLP:** | No |
| **Year:** | 1981 |
| **Results:** | $LC_{50}$ = > 1000 mg/l (Today, this would be termed an $LL_{50}$ = Median Lethal Loading.) |
| **Remarks:** | Water is not a likely environmental release media. The substance is not soluble in water and formed a surface film on the water at the high concentrations. Exposures were therefore to saturated solutions. The loading factor for the test was 0.4 g/L utilizing 5 organisms per dose. |
| **Conclusion:** | No statistically significant mortality or other adverse effects occurred during this study. The 96-hr. $LC_{50}$ for fathead minnows therefore exceeds the solubility limit for the test substance. This result is representative of the class of compounds covered by CAS number 86508-42-1. |
| **Data Quality:** | Klimisch ranking = 2. This study meets most of the criteria for quality testing. Proper documentation of the test method and parameters was followed. However, no |

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| | analysis of the actual test substance concentration was made, nor was there proper analytical characterization of the sample itself. |
| **Reference:** | 3M, Environmental Laboratory – laboratory request number 7044 |

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| **Test Substance:** | **Product I**, production lot number 89. The substance is a clear, colorless, odorless liquid. The purity of the substance cannot be verified to be 100%. |
| **Method:** | Modeled after ASTM E729-80. Standard for conducting acute toxicity tests with fishes, macro-invertebrates, and amphibians. American Society for Testing and Materials, Philadelphia, PA 1980. |
| **Test Type:** | Acute Static |
| **Test solutions:** | Well water used as vehicle. 2 control vessels and 2 vessels containing 1000 mg/l of Product I (direct addition of individual weights). |
| **Test organism:** | Fathead minnow (*Pimephales promelas*) with average length of 2.9 cm and average weight of 0.19 grams. |
| **Exposure Period:** | 96 hours |
| **Analytical Monitoring:** | pH, dissolved oxygen, and temperature. All remained within acceptable parameters throughout the test. |
| **GLP:** | No |
| **Year:** | 1982 |
| **Results:** | $LC_{50}$ = > 1000 mg/l (Today, this would be termed an $LL_{50}$ = Median Lethal Loading.) |
| **Test Remarks:** | Water is not a likely environmental release media. The substance is not soluble in water and remains as a separate phase on the tank bottom. Exposure was therefore to a saturated solution. The loading factor for the test was 0.19 g/L utilizing 30 organisms per dose. |

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| **Conclusion:** | No adverse affects or mortality occurred during this study. The 96-hr. LC50 for fathead minnows therefore exceeds the solubility limit for the test substance. This result is representative of the class of compounds covered by CAS number 86508-42-1. |
| **Data Quality:** | Klimisch ranking = 2. This study meets most of the criteria for quality testing. Proper documentation of the test method and parameters was followed. However, no analysis of the actual test substance concentration was made, nor was there proper analytical characterization of the sample itself. |
| **Reference:** | 3M, Environmental Laboratory – laboratory request number 7981 |

## 5.2 Acute Toxicity to Aquatic Invertebrates

This class of chemicals presents no aquatic toxicity due to the lack of water solubility, as demonstrated in the tests described below on two products.

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| **Test Substance:** | **Product E**, production lot number 102. The purity of the substance cannot be verified to be 100%. The substance is a clear, colorless, odorless liquid. |
| **Method:** | OECD guideline 202 "Daphnia sp., Acute Immobilization Test and Reproduction Test" and US-EPA guideline EG-1 "Daphnid Acute Toxicity Test". |
| **Test Type:** | Acute Static |
| **Test solutions:** | 1 control vessel and test vessels containing substance concentrations of 100, 180, 320, 560, and 1000 mg/l (direct addition of individually measured weights). |
| **Test organism:** | Water flea (*Daphnia magna*), <24 hours old (neonates) |
| **Exposure Period:** | 48 hours |
| **Analytical Monitoring:** | pH, dissolved oxygen, and temperature. All remained within acceptable parameters throughout the test. |
| **GLP:** | No |
| **Year:** | 1986 |

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| **Results:** | $EC_{50}$ = > 1000 mg/L (Today, this would be termed an $EL_{50}$ = Median Effective Loading) |
| **Test Remarks:** | Water is not a likely environmental release media. The substance is not completely soluble in water as droplets were visible on the bottoms of test beakers. Exposure was therefore to a saturated solution. |
| **Conclusion:** | No adverse affects or immobility occurred during this study. The 48-hr. EC50 for *Daphnia magna* therefore exceeds the solubility limit for the test substance. This result is representative of the class of compounds covered by CAS number 86508-42-1. |
| **Data Quality:** | Klimisch ranking = 2. This study meets most of the criteria for quality testing. Proper documentation of the test method and parameters was followed. However, no analysis of the actual test substance concentration was made, nor was there proper analytical characterization of the sample itself. |
| **Reference:** | 3M, Environmental Laboratory – laboratory request number F2539 |

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| **Test Substance:** | **Product F**. The production lot number was not noted. The substance is a clear, colorless liquid. The purity of the substance cannot be verified to be 100%. |
| **Method:** | OECD guideline 202 "Daphnia sp., Acute Immobilization Test and Reproduction Test" and US-EPA guideline EG-1 "Daphnid Acute Toxicity Test". |
| **Test solutions:** | A control and single solution of **Product F** at nominal concentration of 1000 mg/L was created. The test solution was formulated by combining the test substance and filtered natural well water, allowing it to mix in the dard for 20 hours, and filtering (0.45 micron) prior to use in the test. All test vessels containing FX-3300 were initially clear and remained clear through the test. |
| **Type of Test:** | Acute Static |
| **Species:** | Water flea (*Daphnia magna*), <24 hours old (neonates) and noted to be in good condition. |

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| **Exposure Period:** | 48 hours |
| **Analytical Monitoring:** | Information not provided in summary report |
| **GLP:** | No |
| **Year:** | 1991 |
| **Results:** | $EC_{50}$ = > 1000 mg/l |
| **Test Remarks:** | Water is not a likely environmental release media. Though not mentioned in the report summary, chemicals in this compound class are not soluble at the nominal concentration of 1000 mg/L. Therefore, the test solution created would have been a saturated solution, and the testing result would be more accurately expressed as an $EL_{50}$ = Median Effective Loading. |
| **Conclusion:** | No adverse affects or immobility occurred during this study. The 48-hr. EC50 for *Daphnia magna* therefore exceeds the solubility limit for the test substance. This result is representative of the class of compounds covered by CAS number 86508-42-1. |
| **Reference:** | Performing Laboratory: EnviroSystems Division, One Lafayette Road, Hampton, New Hampshire 03842<br>Study Title: Static Acute Toxicity of FX-3300 to the Daphnid, *Daphnia magna*. |

## 5.3 Acute Toxicity to Aquatic Plants

Testing to determine the toxicity of the class of compounds covered by CAS 86508-42-1 to algae or other aquatic plants has not been conducted. Since it is unlikely that the aquatic environment will be significantly exposed to these compounds based on their physical / chemical properties, and data on other phyla has been submitted, further testing is not necessary. 3M submits additional data on bacteria (*Photobacterium phosphoreum*) to support its position that these compounds would not exhibit significant aquatic toxicity.

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| **Test Substance:** | **Product A**, production lot number 115. The purity of the substance cannot be verified to be 100%. The substance is a clear, colorless, odorless liquid. |
| **Method:** | Microbics Microtox® "BASIC" procedure. |

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| **Test solutions:** | 2 control vessels and duplicate test vessels containing nominal substance concentrations of 125, 250, 500, and 1000 mg/L. Test solutions were created from a 2000 mg/L stock solution utilizing Millipore Milli-Q™ water. Stock solution had an initial pH of 5.1, and was adjusted to 6.0 with 0.02 N NaOH. An osmotic adjustment was made using 200 mg NaCl dissolved in 10 mL stock solution. The final appearance of the test solution was described as a "clear, colorless liquid". |
| **Test Type:** | Acute Static |
| **Test organism:** | *Photobacterium phosphoreum* |
| **Exposure Period:** | 30 minutes |
| **Analytical Monitoring:** | light readings, pH |
| **GLP:** | No |
| **Year:** | 1992 |
| **Results:** | 5 minutes: $EC_{50}$ = > 1000 mg/l, percent light loss = 0%<br>15 minutes: $EC_{50}$ = > 1000 mg/l percent light loss = 0%<br>30 minutes: $EC_{50}$ = > 1000 mg/l percent light loss = 0% |
| **Test Remarks:** | Water is not a likely environmental release media. |
| **Conclusion:** | There was no toxicity noted at the nominal concentrations tested. This result is representative of the class of compounds covered by CAS number 86508-42-1. |
| **Data Quality:** | Klimisch ranking = 3. This study does not meet criteria for quality testing. This test fails to properly characterize the concentration of the test substance in solution as noted in the test remarks, and assumption of saturation cannot be made. |
| **Reference:** | 3M, Environmental Laboratory – laboratory request number K1657 |

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| **Test Substance:** | **Product D**, production lot number 115. The purity of the substance cannot be verified to be 100%. The substance is a clear, colorless, odorless liquid. |
| **Method:** | Microbics Microtox® "BASIC" procedure. The highest test concentration used was 2000 mg/L. |
| **Test solutions:** | 3 control vessels and 3 test vessels containing saturated solutions of **Product D**. Test solutions were created by adding 200 mg of sample to 100 mL Millipore Milli-Q™ water, allowing it to mix overnight, covered in the dark at ambient room temperature. Material was noted on the bottom of the vessel. The liquid portion was decanted for testing. Stock solution had an initial pH of 4.5, and was adjusted to 7.9 with 0.1 N NaOH. An osmotic adjustment was made using 200 mg NaCl dissolved in 10 mL stock solution. The final appearance of the test solution was described as a "clear liquid". |
| **Test type:** | Acute Static |
| **Test organism:** | *Photobacterium phosphoreum* |
| **Exposure Period:** | 30 minutes |
| **Analytical Monitoring:** | light readings, pH |
| **GLP:** | No |
| **Year:** | 1992 |
| **Results:** | 5 minutes: $EC_{50}$ = >100% saturated stock solution, percent light loss = 20%<br>15 minutes: $EC_{50}$ = >100% saturated stock solution percent light loss = 29%<br>30 minutes: $EC_{50}$ = >100% saturated stock solution percent light loss = 34% |
| **Test Remarks:** | Water is not a likely environmental release media. |
| **Conclusion:** | The 30 minute $EC_{50}$ light inhibition for *Photobacterium phosphoreum* exceeds the solubility limit for this compound. This result is representative of the class of compounds covered by CAS number 86508-42-1. |

**Data Quality:** Klimisch ranking = 2. This study meets most of the criteria for quality testing. Proper documentation of the test method and parameters was followed. There was no analytical characterization of the sample itself.

**Reference:** 3M, Environmental Laboratory – laboratory request number K2328

# 6.0 Mammalian Toxicity

## 6.1 Acute Toxicity

Acute oral gavage and inhalation toxicity studies are performed to evaluate the effects of a single exposure to very high doses of a test material. A variety of observations are made during exposure and during the usual 2-week recovery period. Results are usually reported as mg/kg (oral toxicity) or as ppm or mg/m3 (inhalation). Occasionally, intraperitoneal studies are performed. These results are usually reported as mg/kg.

**Summary of Acute Toxicity Data:**

Acute oral and inhalation toxicity studies performed with either Compound **Ha** or **C** did not induce lethality or toxicity in any study at any concentration tested. An extremely high dose intraperitoneal injection study performed with Compound **Ha** in the rat resulted in no lethality. Compounds **Ha** and **C**, as representative of the class of PFCs, are considered essentially "non-toxic" by either oral or inhalation exposure.

**Title:** An Acute Inhalation Toxicity Study of T-4502 (**Product Ha**) in the Rat. 1969.

**Test Article:** (**Product Ha**, T-4502) Not further specified

**Method/Guideline:** Not specified

**GLP:** N

**Year Study Performed:** 1969

**Species/Strain:** Charles River Albino rats

**Sex:** Males and Females

**No. of Animals/Sex/Dose:** 7/sex/group

**Route of Administration:** Inhalation

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| **Remarks:** | Fourteen albino rats (seven male and seven female) were exposed to vapor of **Product Ha** in a 70 liter Plexiglass chamber for a period of four hours. The nominal concentration was found to be 41 mg/L air. At the end of the exposure period, four rats were sacrificed (two male and two female) and the lung tissue was examined microscopically. The remaining ten animals were returned to their stock cages and observed for the following 14 days. |
| **Results:** | There were no deaths, untoward behavioral reactions or adverse body weight effects caused by the inhalation of the test material. Necropsy of all test animals did not reveal any gross pathological alterations. Microscopic examination of the lung tissue in four animals did not reveal any histopathological alterations. |
| **Conclusions:** | The compound did not induce toxicity by inhalation. |
| **Reference:** | 1969. *An Acute Inhalation Toxicity Study of FC-40 in the Rat.* IBT No. N7109, Industrial Bio-Test Laboratories, Inc. |
| **Remarks:** | Similar results were obtained in a previous study (T-4501 done in 1962 on **Product Hb**) on three species (rats, mice, and guinea pigs) with concentrations up to 17 mg/liter. |

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| **Title:** | **Product Ha** (T-2740CoC) Acute Oral Toxicity (LD50) Study in Rats. 1980. |
| **Test Article:** | Identity: T-2740CoC **Product Ha** Lot 153 |
| **Method/Guideline:** | Riker Test Method 605A |
| **GLP:** | No, but was audited by the QA group |
| **Year Study Performed:** | 1980 |
| **Species/Strain:** | Charles River Albino Rats |
| **Sex:** | Male and Female |
| **No. of Animals/Sex/Dose:** | 5/sex/dose |

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| **Vehicle:** | None |
| **Route of Administration:** | Gavage |
| **Remarks:** | The rats were administered the test article at a dosage level of 5,000 mg/kg, followed by a 14 day observation period. Initial and final body weights, mortalities and adverse reactions were recorded. Necropsies were performed at the end of the 14 day observation period. |
| **Results:** | LD50: >5,000 mg/kg. No untoward behavioral reactions or deaths occurred during the 14 day observation period and body weight gains were noted for all animals which survived the test period. Necropsies performed at termination of the study revealed no visible lesions. |
| **Conclusions:** | The compound can be considered practically non-toxic on an acute oral basis. |
| **Reference:** | 1980. *FC-40 Acute Oral Toxicity (LD50) Study in Rats.* Study No. T-2740CoC, Riker Safety Evaluation Laboratory, St. Paul, MN. |
| **Remarks:** | Similar study, except for 10 g/kg dose, conducted in 1972 (T-457) also resulted in no deaths and no significant gross findings on autopsy. |

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| **Title:** | An Acute Intraperitoneal Toxicity Study of T-4502 (**Product Ha**) in the Rat. |
| **Test Article:** | **Product Ha**, T4502, not further specified. |
| **Method/Guideline:** | Not specified |
| **GLP:** | No, no QA/QC indicated |
| **Year Study Performed:** | 1969 |
| **Species/Strain:** | Charles River albino rats |
| **Sex:** | Male and Female |

**No. of Animals/Sex/Dose:** 2/sex/group

**Route of Administration:** Intraperitoneal injection

**Remarks:** Undiluted **Product Ha** was administered by injection into the peritoneal cavity to three groups of four rats (2 male and 2 female) each. The dose groups were 15.4, 23.1, and 34.6 g/kg.

**Results:** There were no deaths. Abnormal stance, hypoactivity, and muscular weakness was observed at all doses within 15 minutes of compound administration. Ruffled fur was also observed at the high dose level. Weight gains were normal. No lesions were observed at necropsy. Necropsy revealed clear fluid in the abdominal cavity of all animals; and white soft ovoid masses attached to the mesentery near the blood vessels and/or free floating in the cavity. Watery vacuoles also were found in the subcutaneous tissue of the ventral abdomen.

**Conclusions:** The acute intraperitoneal LD50 for **Product Ha** is greater than 34.6 grams per kilogram of body weight. Therefore, this material may be considered to be practically non-toxic when administered intraperitoneally.

**Reference:** 1969. *An Acute Intraperitoneal Toxicity Study of FC-40 in the Rat.* IBT No. A7108, Industrial Bio-Test Laboratories, Inc.

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**Title:** Acute Oral Toxicity Study of T-5333 in Rats (OECD Guidelines)

**Test Article**: 98.8 % perfluorohexane (T-5333, Fluorinert®Brand Electronic Liquid **Product C**, Lot 629)

**Method/Guideline:** Organization for Economic Cooperation and Development's Guidelines for Testing of Chemicals, Section 401 (adopted May 12, 1981).

**GLP:** Yes

**Year Study Performed:** 1991

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| **Species/Strain:** | Charles River Albino Rats |
| **Sex:** | Male and Female |
| **No. of Animals/Sex/Dose:** | 5/sex |
| **Vehicle:** | None |
| **Route of Administration:** | Gavage |
| **Remarks:** | A single dose of 5 mg/kg was tested. All dose levels were administered as volumes of 2.99 ml/kg body weight. The rats weighed 208-240 g at the beginning of the study immediately prior to dosing, and weights were recorded at Day 7 and Day 14. The rats were observed for abnormal signs during the four hours after exposure, and daily thereafter for 14 days. |
| **Results:** | No deaths occurred. All animals appeared normal and gained weight. There were no visible lesions found at gross necropsy. |
| **Conclusions:** | The estimated oral LD50 is greater than 5.0 g/kg |
| **Reference:** | 1991. *Acute Oral Toxicity Study of T-5333 in Rats (OECD Guidelines).* Final Report. Hazleton Wisconsin Study Number 10102633. |

## 6.2 Primary Eye and Skin Irritation

Primary eye and skin studies performed with either Compound **Ha** or **C** all resulted in no adverse effects. Compounds **Ha** and **C**, as representative of the class of PFCs are considered "non-irritating" to the eyes and skin.

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| **Title:** | Primary Eye Irritation/Corrosion Study of T-5333 in Rabbits (OECD Guidelines) |
| **Test Article**: | 98.8 % perfluorohexane (T-5333, Fluorinert®Brand Electronic Liquid **Product C**, Lot 629) |
| **pH of test material:** | It was not possible to measure the pH. |
| **Method/Guideline:** | "Acute Eye Irritation/Corrosion," Organization for Economic Cooperation and Development's Guidelines for |

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| | Testing of Chemicals, Section 405 (adopted May 12, 1981). |
| **Test Type:** | *in vivo* |
| **Species/Strain/Cell Type:** | Rabbits/ albino |
| **Sex:** | Male and Female |
| **No. of Animals/Sex/Dose:** | One female and two males |
| **Total Dose:** | 0.1 ml |
| **Vehicle:** | None |
| **Contact Time:** | Maximum of 72 hr |
| **Grading scale:** | Draize |
| **Remarks:** | Three albino rabbits had 0.1 ml of test article applied undiluted to the conjunctival sac of one eye. Irritation was scored at 1, 24, 48 and 72 hours after application of test article into the eye. |
| **Results:** | Primary irritation score was zero. All cases report the primary eye irritation scores were 0.0, indicating no observation of corneal, iridal or conjunctival irritation at any time. |
| **Conclusions:** | The test article was non-irritating to the eye under the test conditions. |
| **Reference:** | 1991. *Primary Eye Irritation/Corrosion Study of T-5333 in Rabbits (OECD Guidelines)*. Final Report. Hazleton Wisconsin Study Number 10102635 |

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|---|---|
| **Title:** | Eye and Skin Irritation Report on Sample T-1495. |
| **Test Article**: | (**Product Ha**, T-1495) Not further specified |
| **pH of Test Article:** | Not applicable |
| **Method/Guideline:** | Described in Section 1500.42 - Hazardous Substances and Articles, Administration and Enforcement |

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| | Regulations, Federal Register, Vol. 38, No. 187, P. 27019, 27 September 1973. |
| **Test Type:** | *in vivo* |
| **Species/Strain/Cell:** | Albino rabbit |
| **Sex:** | Not specified |
| **No. of Animals/Sex/Dose:** | 6/single dose |
| **Total dose:** | 0.1 ml, concentration not specified, total dose not specified |
| **Contact Time:** | 7 days |
| **Observation Period:** | 1hr, 24 hr, 48 hr, 72 hr, 5 and 7 days |
| **Scoring Method Used:** | Grading system outlined in the "Illustrated Guide for Grading Eye Irritation by Hazardous Substances." |
| **Remarks:** | One tenth of a milliliter (0.1 ml) of the experimental material was instilled into the right eyes of the test animals while the other eyes remained untreated to serve as controls. The test material was not washed from the eyes. |
| **Results:** | Irritation score of zero for all ocular tissues (cornea, iris, and conjunctivae) for all test animals at all observation periods. |
| **Conclusions:** | The subject material is not an ocular irritant. |
| **Reference:** | 1976. *Eye and Skin Irritation Report on FC-40 (T-1495)*. Primary Eye Irritation Study Report, May 21, 1976, Biosearch, Inc. |
| **Other:** | Similar study done in 1969 (T-4953) on FC-43 (also referred to as **Product Hb**), Lot 137 concluded test material was practically non-irritating to the eye. |

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|---|---|
| **Title:** | Primary Dermal Irritation/Corrosion Study of T-5333 in Rabbits (OECD Guidelines) |

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|---|---|
| **Test Article**: | 98.8 % perfluorohexane (T-5333, Fluorinert®Brand Electronic Liquid **Product C**, Lot 629) |
| **pH of Test Material:** | It was not possible to measure the pH |
| **Method/Guideline:** | "Acute Dermal Irritation/Corrosion," Organization for Economic Cooperation and Development's Guidelines for Testing of Chemicals, Section 404 (adopted May 12, 1981). |
| **Test Type:** | *in vivo* |
| **Species/Strain/Cell Type:** | Rabbits/ albino |
| **Sex:** | Both sexes |
| **No. of Animals/Sex/Dose:** | One male and two females |
| **Total Dose:** | 0.5 ml semi-occluded on shaved skin |
| **Vehicle:** | None |

**Length of time test material is in contact with animal/cell:** 4 hr

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| **Grading Scale:** | Scales of 1 to 4, increasing in severity for erythema and eschar (combined) formation and edema formation are used and scores for each endpoint are summed such that the score equals the sum of erythema and edema scores. Scoring based on Draize (1975). "Primary Irritation of the Skin," In: Appraisal of the Safety of Chemicals in Foods, Drugs and Cosmetics - Dermal Toxicity, Association of Food and Drug Officials of the U. S., pp. 46-47 (1975). |
| **Remarks:** | Three albino rabbits had their backs shaved and 0-5 ml of test article applied undiluted. This was covered with a 2.5 cm2 patch of gauze and semi-occluded under loose Saran wrap secured with Elastoplast. Exposure was four hours, after which patches were removed, the sites cleaned with tap water and disposable towels and scored 30 minutes and 24, 48 and 72 hours after removal. |
| **Results:** | Primary irritation score of 0.0. In all cases it is reported the primary skin irritation scores were 0.0, indicating no observation of erythema or edema on the test sites. |

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| **Conclusions:** | The test article was non-irritating to skin under the test conditions. |
| **References:** | 1975. *Eye and Skin Irritation Report on Sample T-1117*. Project No.4102871, WARF Institute Inc. |

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|---|---|
| **Title:** | Eye and Skin Irritation Report on Sample T-1495. 1976. |
| **Test Article**: | (**Product Ha**, Sample T-1495) Not further specified |
| **pH of Test Material:** | Not specified |
| **Method/Guideline:** | Described in Section 1500.41 - Hazardous Substances and Articles, Administration and Enforcement Regulations, Federal Register, Vol. 38, No. 187, P. 27019, 27 September 1973. |
| **Test Type:** | *in vivo* |
| **Species/Strain/Cell Type:** | Rabbits/ albino |
| **Sex:** | Not specified |
| **No. of Animals/Sex/Dose:** | 6 total |
| **Total Dose:** | 0.5 ml, concentration not specified; total dose not specified |
| **Vehicle:** | None specified |

**Length of Time Test Material is in Contact with Animal/Cell:** 72 hr

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| **Grading Scale:** | Separate scores for erythema formation and edema formation are summed. The Draize method of scoring was employed. |
| **Remarks:** | Six albino rabbits had their hair clipped over a wide area and five tenths of one milliliter (0.5 ml) of test material was placed on abraded and intact prepared test sites on the same rabbit, then covered with gauze patches. An impervious material was wrapped snugly around the trunks of the animals to hold the patches in place. After 24 hours and 72 hours the coverings were removed and |

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| | the degree of erythema and edema was recorded according to a standardized scale. |
| **Results:** | In all cases it is reported the primary skin irritation scores were 0; which indicates no reddening or swelling detected. |
| **Primary Irritation Score:** | 0.0 |
| **Remarks:** | No |
| **Conclusions:** | The subject material would not be classified as a primary irritant to albino rabbits. |
| **References**: | 1976. *Eye and Skin Irritation Report on FC-40 (T-1495).* Primary Skin Irritation Study Report, May 21, 1976, Biosearch, Inc. |
| **Other:** | Similar study done in 1969 (T-4953) on **Product Hb**, Lot 137 concluded test material was non-irritating to the skin. |

## 6.3 Genotoxicity

Two reverse mutation assays are presented as representative of the PFC class. Both utilized the *Salmonella typhimurium* test system (Ames assay). In the case of Compound C, the test system could not be adequately dosed due to volatility of the test material and the inability to find an appropriate solvent. For Compound **H**, cytotoxicity was reported at the highest dose tested, suggesting that the test system could be adequately dosed. No evidence of mutation was reported in the assay with Compound **H**. Although studies from forward mutation and chromosome aberration studies have not been performed, the chemical and physical properties of the class suggest that there is no reason to believe that effects would be observed in these assays. Therefore, 3M does not intend to do these tests.

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| **Title:** | Mutagenicity Test on T-5333 in the Salmonella/Mammalian-Microsome Reverse Mutation Assay (Ames Test) |
| **Test Article**: | 98.8 % perfluorohexane (T-5333, Fluorinert®Brand Electronic Liquid **Product C**, Lot 629) |
| **Method/Guideline:** | Ames et al. (1975). Methods for Detecting Carcinogens and Mutagens with the Salmonella/Mammalian-Microsome Mutagenicity Test. Mutation Research 31:347-364. |

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| | Distlerath et al. (1984). Aliphatic Halogenated Hydrocarbons Produce Volatile Salmonella Mutagens. Mutation Research 136:55-64. |
| **Test Type:** | Reverse mutation, with and without activation |
| **Test System:** | Bacterial (Salmonella typhimurium) |
| **GLP:** | Yes |
| **Year Study Performed:** | 1991 |
| **Cell-Type/Line:** | Salmonella typhimurium tester strain TA 100 |
| **Metabolic Activation:** | S9 microsomal fraction purchased from Molecular Toxicology, Annapolis, MD |
| **Concentrations Tested:** | 10.0, 25.0, 50.0, 100, 150 and 200 µl per plate for four and twenty-four hours, and 200, 400, 500, 600, 800 and 1000 µl per plate for twenty-four hours |
| **Statistical Methods Used:** | None |
| **Remarks:** | 1000 µl per plate was the highest amount which could be tested in the system. |
| **Results:** | It was concluded that the test article could not be adequately tested using the Salmonella Mutation Assay based on volatility, lack of solubility in suitable solvents (water, 100 % ethanol, dimethylsufoxide, acetone and dimethylformamide) and the inability to demonstrate by cytotoxicity that the test system could be adequately dosed in a vapor exposure system. |
| **Remarks:** | Volatility, lack of solubility in all commonly employed solvents and inability to demonstrate cytotoxicity limited the utility of the assay system for this test article. |
| **Conclusions:** | The test article could not be adequately tested due to unique physical properties and lack of evidence for exposure of the test system (cytotoxicity). |
| **Reference:** | 1991. *Mutagenicity Test on T-5333 in the Salmonella/Mammalian-Microsome Reverse Mutation Assay (Ames Test).* Final Report. Hazleton Laboratories America, Project ID 12615-0-401 |

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| **Title:** | Mutagenicity Evaluation of T-2007 CoC. 1978. |
| **Test Article**: | (T-2007CoC, **Product Ha**) Not further specified |
| **Method/Guideline:** | Ames et al., Mutation Research 31:347, 1975 |
| **Test Type:** | Reverse mutation, with and without activation |
| **Test system:** | Bacterial |
| **GLP:** | No, but SOP's listed |
| **Year Study Performed:** | 1978 |
| **Cell-Type/Line:** | Salmonella typhimurium strains TA1535, TA100, TA98, TA1537, TA1538, and Saccharomyces cerevisiae strain D4 with and without activation. |
| **Metabolic Activation:** | S9 liver homogenate from Aroclor 1254 induced Sprague-Dawley rats |
| **Concentrations Tested:** | 10 ul/plate, 25 ul/plate, 50 ul/plate, 100 ul/plate with and without activation. |
| **Statistical Methods Used:** | None |
| **Remarks:** | Spot test procedure used. |
| **Results:** | The test article was not genotoxic when tested either with or without metabolic activation. Cytotoxicity was noted at the highest dose. The low dose in all cases was below a concentration that demonstrated any toxic effect. There were no test-specific confounding factors. Mutation frequencies were within the range of the vehicle controls. |
| **Conclusions:** | The test article was considered non-mutagenic under the study conditions utilized. |
| **Reference:** | Mutagenicity Evaluation of T-2007 CoC, Final Report. LBI Project No. 20838, January, 1978, Litton Bionetics, Inc. |

## 6.4 Repeat Dose Toxicity

Toxicity has not been observed in inhalation and oral repeat-dose toxicity studies. Inhalation exposure for two to thirteen weeks to Compound **H** at concentrations up to 50,000 ppm were without effect. Similarly, oral dosing with Compound **H** for thirty days at levels up to 2000 mg/kg/day did not produce effects. Inhalation of a saturated atmosphere of Compound **C** for thirty days did not produce effects that were directly attributable to treatment.

| | |
|---|---|
| **Title:** | Two-Week Repeat-Dose Preliminary Inhalation Toxicity Study in Rats with T-5333 (**Product C**) |
| **Test Article:** | 98.8 % perfluorohexane (T-5333, Fluorinert®Brand Electronic Liquid **Product C**, Lot 629) |
| **Method/Guideline:** | Not specified |
| **Study Duration:** | Exposure occurred six hours a day, five days a week for two weeks and on the first day of the following week. |
| **GLP:** | Yes |
| **Year Study Performed:** | 1992 |
| **Species/Strain:** | Rats, Sprague Dawley |
| **Sex:** | Both sexes |
| **Number per Group:** | 10 male and 10 females |
| **Route of Administration:** | Inhalation |
| **Doses and Frequency:** | Air only and 50129 parts per million. Exposure occurred six hours a day, five days a week for two weeks and on the first day of the following week. |
| **Post-Observation Period:** | None |
| **Statistical Methods Used:** | Separate analyses for males and females. Food and water intake were analyzed on a cage basis with cumulative average daily intake per group used as the comparative between groups. Each animal was used as its own control for body-weight gain and organ weight data. If relative frequency of the mode exceeded 75 %, the proportion with values different than the mode was used. Bartlett's test for heterogeneity of variance between treatments was used, and if significant, a log transformation was tried. If |

| | |
|---|---|
| | no heterogeneity was found or a transformation was satisfactory, one-way ANOVA was used. If significant heterogeneity of variance was present, Kruskal-Wallis analysis of ranks was used. ANOVA was followed by Student's t-test or the William's test for dose-related response. Kruskal-Wallis was followed by Shirley's test. |
| **Remarks:** | Observations were made for mortality, clinical signs, weight gain, food consumption, water consumption, macroscopic pathology and organ weights. |
| **Results:** | No treatment-related effects were observed. |
| **Remarks:** | The study was conducted adequately under GLP. |
| **Conclusions:** | The test article did not produce effects under the test conditions. |
| **Reference:** | 1992. *Two-Week Repeat-Dose Preliminary Inhalation Toxicity Study in Rats with T-5333 (PF-5060).* Final Report. Huntingdon Research Center, Ltd. Reference MIN 56/911538 |

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| | |
|---|---|
| **Title:** | T-5333 90-Day Inhalation Study in Rats |
| **Test Article:** | 98.8 % perfluorohexane (T-5333, Fluorinert® Brand Electronic Liquid **Product C**, Lot 629) |
| **Method/Guideline:** | Not specified |
| **Study duration:** | Exposure occurred six hours a day, five days a week for 13 weeks. |
| **GLP:** | Yes |
| **Year Study Performed:** | 1992 |
| **Species/Strain:** | Rats, Sprague Dawley |
| **Sex:** | Both sexes |
| **Number per group:** | 10 male and ten females. Study design included recovery group animals in the control and high-dose groups. |

**Route of Administration:** Inhalation by whole-body exposure

**Doses and frequency:** Air only and 500, 15000 and 50000 parts per million (4987, 15060 and 49821 parts per million measured). Exposure occurred six hours a day, five days a week for two weeks and on the first day of the following week.

**Post-observation period:** Two weeks for recovery control and high-dose animals

**Statistical methods used:** Separate analyses for males and females. Food and water intake were analyzed on a cage basis with cumulative average daily intake per group used as the comparative between groups. Each animal was used as its own control for body-weight gain and organ weight data. If relative frequency of the mode exceeded 75 %, the proportion with values different than the mode was used. Bartlett's test for heterogeneity of variance between treatments was used, and if significant, a log transformation was tried. If no heterogeneity was found or a transformation was satisfactory, one-way ANOVA was used. If significant heterogeneity of variance was present, Kruskal-Wallis analysis of ranks was used. ANOVA was followed by Student's t-test or the William's test for dose-related response. Kruskal-Wallis was followed by Shirley's test.

**Remarks:** Observations were made for mortality, clinical signs, weight gain, food consumption, ophthalmoscopy, hematology, biochemistry, macroscopic pathology, microscopic pathology and organ weights.

The following hematology and biochemistry parameters and were evaluated:
Packed cell volume
Hemoglobin
Red cell count
Mean corpuscular hemoglobin concentration
Mean corpuscular volume
Total white cell count
Platelet
Differential cell count
Presence or absence of abnormal cells
Thrombotest
Reticulocyte count

Creatine phosphokinase

Total protein
Albumin
Globulin
Urea Nitrogen
Alkaline phosphatase
Total bilirubin
Creatinine
Sodium
Potassium
Calcium
Inorganic phosphorus
Chloride
Cholesterol
Glucose
Glutamic-pyruvic transamina
Glutamic-oxaloacetic transaminase
Gamma-Glutamyltransferase

The following organs were weighed

| | |
|---|---|
| Adrenals | Brain |
| Heart | Kidneys |
| Liver | Lungs |
| Ovaries | Pituitary |
| Prostate | Spleen |

Testes (with epididymides)
Thymus

Macroscopic appearance of all the tissues was noted and the * below indicates those tissues evaluated microscopically.

| | |
|---|---|
| Adrenals* | alimentary tract* |
| Esophagus* | stomach* |
| Duodenum* | jejunum* |
| Ileum* | caecum |
| Colon* | rectum |
| Aorta* | brain* |
| Eyes* | femur |

Head (paranasal tissues, oral cavity, nasopharynx, middle ear, teeth, eyelids, lachrymal gland, harderian gland, and zimbals gland)

| | |
|---|---|
| Heart* | kidneys* |
| Larynx* | liver* |
| Lungs* | lymph nodes* |

Mammary gland
Nasal passages*

| | |
|---|---|
| Q optic nerve | ovaries* |

| | |
|---|---|
| Oviduct | pancreas* |
| Pharynx* | pituitary* |
| Prostate | salivary gland* |
| Sciatic nerve | seminal vesicles |
| Skeletal muscle | |
| Skin | |
| Spinal column | |
| Spinal cord* | Spleen* |
| Sternum* | Testes (with epididymes)* |
| Thymus* | thyroid (with parathyroids)* |
| Tongue | trachea (including bifurcation)* |
| Ureter | urinary bladder* |
| Uterus* | vagina |
| Gross abnormalities* | |

**Results:** No treatment-related effects were observed. The NOAEL for the study was 49821 parts per million by volume in air.

**Conclusions:** The test article did not produce effects under the test conditions.

**Reference:** 1992. *T-5333 90-Day Inhalation Study in Rats. Final Report.* Huntingdon Research Center, Ltd. Reference MIN 59/920819.

*** * ***

**Title:** Subacute Inhalation Study in Rats on T-1549 (**Product Hb**)

**Test Article:** (**Product Hb**, T-1549).

**Method/Guideline:** Not specified.

**Study Duration:** 30 Days

**GLP:** No

**Year Study Performed:** 1977

**Species/Strain:** Rats/Sprague-Dawley from Charles River

**Sex:** Both

| | |
|---|---|
| **Number per Dose Group:** | 26 exposed (16 males and 10 females)/16 controls (11 males and 5 females) |
| **Route of Administration:** | Inhalation |
| **Doses and Frequency:** | Saturated atmosphere for seven hours per day, five days per week, for a total of 30 exposures. Concentration expressed as mls T-1549 used per cubic meter total air volume flowed through the system (average 7.28 $ml/m^3$). |
| **Post-Observation Period**: | none, necropsy done at end of experiment |
| **Statistical Methods Used:** | t-test |
| **Remarks:** | Hematology, clinical chemistry, and histopathology done on 5 each of test males and females, and 3 each of control males and females.<br><br>Hematology examination included RBC, WBC, hemoglobin, HCT, MCV, MCH.<br><br>Blood chemistry analysis included glucose, creatinine, urea, calcium, globulin, cholesterol, triglyceride, iron, protein, albumin, bilirubin, D. bilirubin, alk. Phos, SGOT, I. Bilirubin.<br><br>Animal weights were taken. Organ weights were not. All major organs except the brain were examined macroscopically and the lung and liver were examined microscopically. |
| **Results:** | The male test rats gained less weight during the study period than the male control rats. However, the female test rat weight pattern was similar to the female controls. The female test rats had lower mean corpuscular hemoglobin (MCH) concentrations and higher mean corpuscular volumes (MCV) than the female control rats. A reduced serum glutamic oxaloacetic transaminase (SGOT) level was observed in the female test rats. The male test rats exhibited an elevated blood iron level and the female test rats exhibited a lower blood iron level than the controls. With the exception of thickened alveolar septa and focal fatty degeneration of liver which were observed in both control and test animals, no pathology was observed which was attributed to the exposure experience. |

| | |
|---|---|
| **Statistical Results:** | The female test rats lower MCH and higher MCV were significantly different from the control group at P <0.05. The male test rats higher blood iron level was significantly different from the controls at P <0.05. The female test rats lower SGOT was significantly different from the control group at p <0.05. |
| **Remarks:** | Liver histology results in both the control and test groups were comparable and unremarkable. |
| **Conclusions:** | The one-month vapor inhalation toxicity of **Product Hb** was found to be low. The lack of any pattern or trend in the hematology or clinical chemistry deviations indicates that there is no direct dose-response relationship and questions the significance of the observed changes. |
| **Reference:** | 1977. *Report on the 30 day saturated vapor inhalation study on T-1549.* Report No. 3, Laboratory No. R16, Toxicology Research Laboratory, University of California, San Francisco. |

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| | |
|---|---|
| **Title:** | 4-Week Oral Gavage Toxicity Study with T-5333 in Rats |
| **Test Article:** | 98.8 % perfluorohexane (T-5333, Fluorinert®Brand Electronic Liquid **Product C**, Lot 629) |
| **Method/Guideline:** | None |
| **Study duration:** | Four weeks |
| **GLP:** | Yes |
| **Year Study Performed:** | 1992 |
| **Species/Strain:** | Rats, Crl:CD ®BR VAF/Plus® |
| **Sex:** | Both sexes |
| **Number per Group:** | 5 per sex per group |
| **Route of Administration:** | Oral Gavage |

**Doses and Frequency:** Control (0.9 % NaCl at 1 ml/kg) and treatment groups of 200, 1000 and 2000 mg/kg body weight/ day (given in volumes of 0.104, 0.520 and 1.04 ml/kg, respectively). Doses were given by oral gavage once per day.

**Post-Observation Period:** None

**Statistical Methods Used:** Levene's test was used for variance homogeneity. Analysis of variance was done on homogenous or transformed data. If the ANOVA was significant, Dunnett's t-test was used for pair-wise comparisons between groups. One-way ANOVA was used to analyze body weights, cumulative body-weight gains, food consumption, clinical chemistry and hematology values (except RBC morphology), organ weights, organ-to-body-weight percentages, and organ-to-brain-weight ratios. Comparisons between groups were made at the 5.0 % two-tailed probability level.

**Remarks:** Observations were made for mortality, clinical signs, weight gain (body weights and cumulative weight gain), food consumption, water consumption, clinical pathology (hematology and clinical chemistry), and anatomical pathology (organ weights, organ-to-body-weight percentages, organ-to-brain-weight ratios, macroscopic and microscopic observations).

Hematology parameters included red blood cell count, hemoglobin, hematocrit, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, platelet count, prothrombin time, white blood cell count, differential blood cell count and blood cell morphology.

Clinical chemistry parameters included glucose, urea nitrogen, creatinine, total protein, albumin, globulin, total bilirubin, cholesterol, aspartate aminotransferase, alanine aminotransferase, alkaline phosphatase, calcium, inorganic phosphorus, sodium, potassium and chloride.

Tissues weighed included adrenals, brain, kidneys, liver, ovaries, and testes.

| | |
|---|---|
| | Tissues examined microscopically included adrenals, brain, heart, kidneys, lesions, liver, lungs, ovaries, spleen, testes. |
| **Results:** | No significant treatment-related effects were observed. |
| **Conclusions:** | The test article did not produce effects under the test conditions. The no-observable-effect level is greater than 2000 mg/kg/day. |
| **Reference:** | 1992. *4-Week Oral Gavage Toxicity Study with T-5333 in Rats.* Final Report. Hazleton Wisconsin, Study Number HWI 6329-102. |

## 6.5 Reproductive Toxicity

As detailed earlier, PFCs are both chemically and biologically unreactive. Due to their high volatility and lack of solubility in biological media, no toxicity is attributed to these materials even at very high doses. In fact, perfluorochemicals structurally similar to those discussed have been used to "rescue" respiratory function in premature infants(1-9).

As evidenced by the human health and environmental toxicity endpoints that have been investigated to date, the materials within this class are all exceedingly low in toxicity. This class of materials is among the least toxic compounds known. The same physical/chemical properties that dictate the mechanisms of biological interaction in the studies conducted to date would also dictate the result of any longer term studies or studies intended to investigate other endpoints such as reproductive toxicity. On this basis, and in the interest of animal welfare, it has never been deemed prudent to pursue any further toxicological investigations with this class of materials. Accordingly, 3M proposes to rely on existing data for other endpoints and will not undertake a reproductive study. Please consider, however, that a reproductive assessment is possible by evaluating the reproductive organs from one of the repeat dose studies. The 90-day study will be used for this purpose and summarized in robust summary format.

| | |
|---|---|
| **Title:** | T-5333 90-Day Inhalation Study in Rats |
| **Test Article:** | 98.8 % perfluorohexane (T-5333, Fluorinert® Brand Electronic Liquid **Product C**, Lot 629) |
| **Method/Guideline:** | Not specified |
| **Study duration:** | Exposure occurred six hours a day, five days a week for 13 weeks. |
| **GLP:** | Yes |

| | |
|---|---|
| **Year Study Performed:** | 1992 |
| **Species/Strain:** | Rats, Sprague Dawley |
| **Sex:** | Both sexes |
| **Number per group:** | 10 male and ten females. Study design included recovery group animals in the control and high-dose groups. |
| **Route of Administration:** | Inhalation by whole-body exposure |
| **Doses and frequency:** | Air only and 500, 15000 and 50000 parts per million (4987, 15060 and 49821 parts per million measured). Exposure occurred six hours a day, five days a week for two weeks and on the first day of the following week. |
| **Post-observation period:** | Two weeks for recovery control and high-dose animals |
| **Statistical methods used:** | Separate analyses for males and females. Food and water intake were analyzed on a cage basis with cumulative average daily intake per group used as the comparative between groups. Each animal was used as its own control for body-weight gain and organ weight data. If relative frequency of the mode exceeded 75 %, the proportion with values different than the mode was used. Bartlett's test for heterogeneity of variance between treatments was used, and if significant, a log transformation was tried. If no heterogeneity was found or a transformation was satisfactory, one-way ANOVA was used. If significant heterogeneity of variance was present, Kruskal-Wallis analysis of ranks was used. ANOVA was followed by Student's t-test or the William's test for dose-related response. Kruskal-Wallis was followed by Shirley's test. |
| **Remarks:** | Observations were made for mortality, clinical signs, weight gain, food consumption, ophthalmoscopy, hematology, biochemistry, macroscopic pathology, microscopic pathology and organ weights. |
| **Results:** | No treatment-related effects were observed. The NOAEL for the study was 49821 parts per million by volume in air. |

| | |
|---|---|
| **Conclusions:** | The test article did not produce effects under the test conditions, including effects that would be associated with reproductive toxicity. |
| **Reference:** | 1992. *T-5333 90-Day Inhalation Study in Rats. Final Report.* Huntingdon Research Center, Ltd. Reference MIN 59/920819. |

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## 6.6 Development and Teratogenicity Toxicity

As detailed earlier (1.3 Metabolism/Toxicology Summary), PFCs are characterized as being both chemically and biologically unreactive. Due to their high volatility and lack of solubility in biological media, no toxicity is attributed to these materials even at very high doses. In fact, perfluorochemicals structurally similar to those discussed have been used to "rescue" respiratory function in premature infants.

As evidenced by the human health and environmental toxicity endpoints that have been investigated to date, the materials within this class are all exceedingly low in toxicity. This class of materials is among the least toxic compounds known. The same physical/chemical properties that dictate the mechanisms of biological interaction in the studies conducted to date would also dictate the result of any longer term studies or studies intended to investigate other endpoints such as developmental toxicity. On this basis, and in the interest of animal welfare, it has never been deemed prudent to pursue any further toxicological investigations with this class of materials. Therefore 3M will not conduct developmental testing.